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GB 2363077 A
WO 1999/056643 A1
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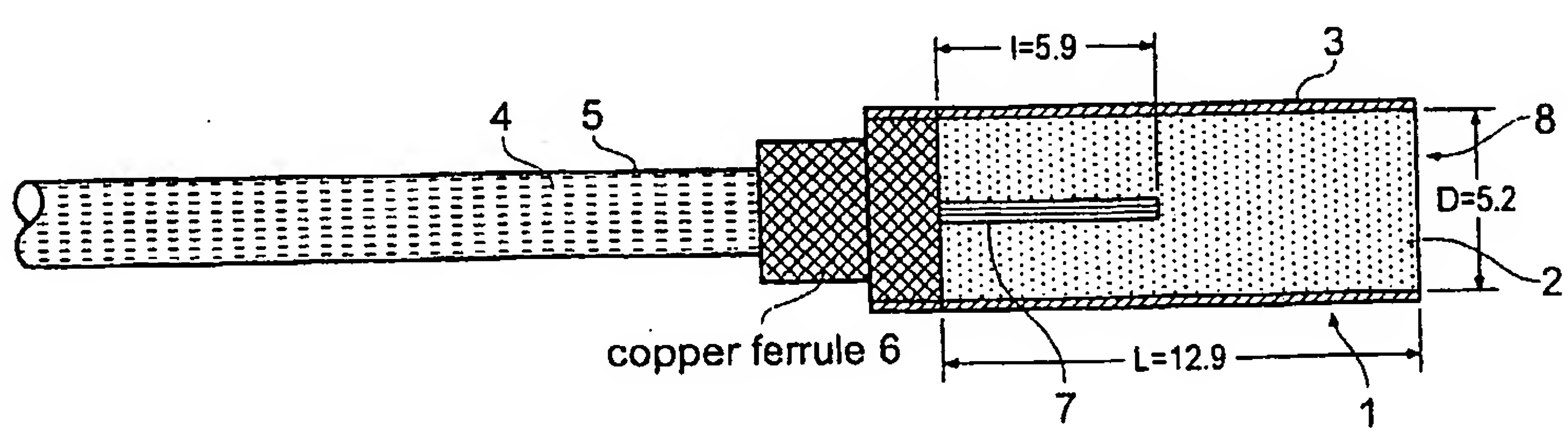
Other: ONLINE : WPI EPODOC JAPIO BIOSIS MEDLINE INSPEC

(54) Abstract Title
Microwave Applicator

(57) A microwave applicator comprising a coaxial electrical input (4)and a waveguide (1) filled with dielectric (2), an inner conductor (7) of the coaxial input extending longitudinally within one end of the waveguide to launch microwaves in the TM_{01} mode to travel to the distal end face (8) of the waveguide so that microwaves are transmitted when the distal end face is contacted by the biological tissue to be treated.

The waveguide is preferably arranged so that when the distal face is against tissue, the reflections at this face back into the waveguide are minimised and froward transmission is enhanced. Also, the waveguide may be arranged so that when the distal face is removed from tissue and this face is in air or gas, that reflections from this face back into the waveguide are enhanced.



dimensions in mm

Fig. 1

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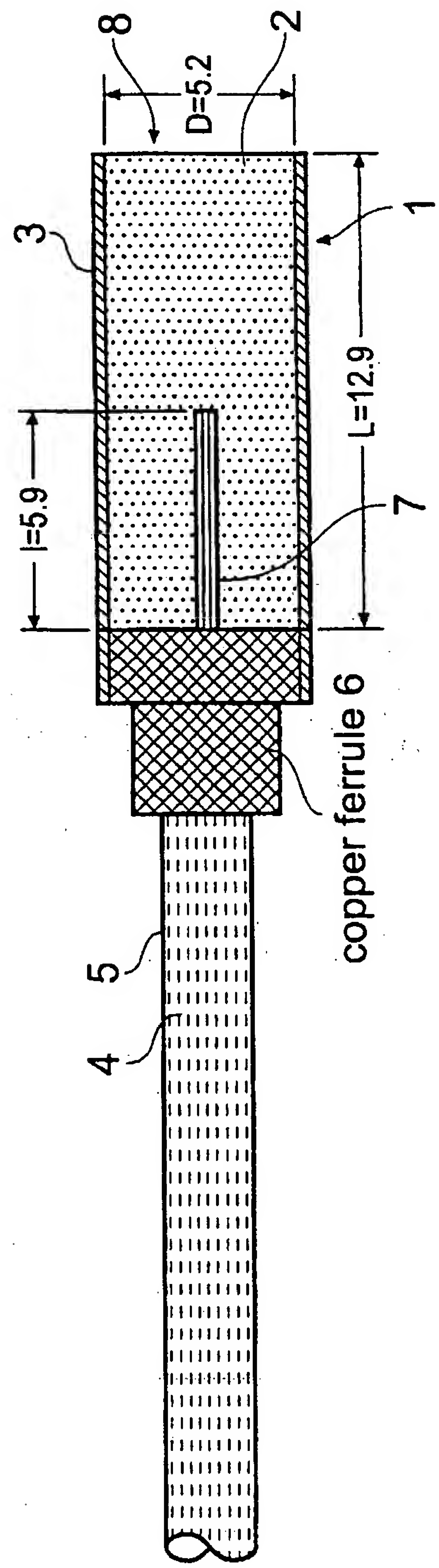
At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

This print takes account of replacement documents submitted after the date of filing to enable the application to comply with the formal requirements of the Patents Rules 1995



dimensions in mm

Fig. 1

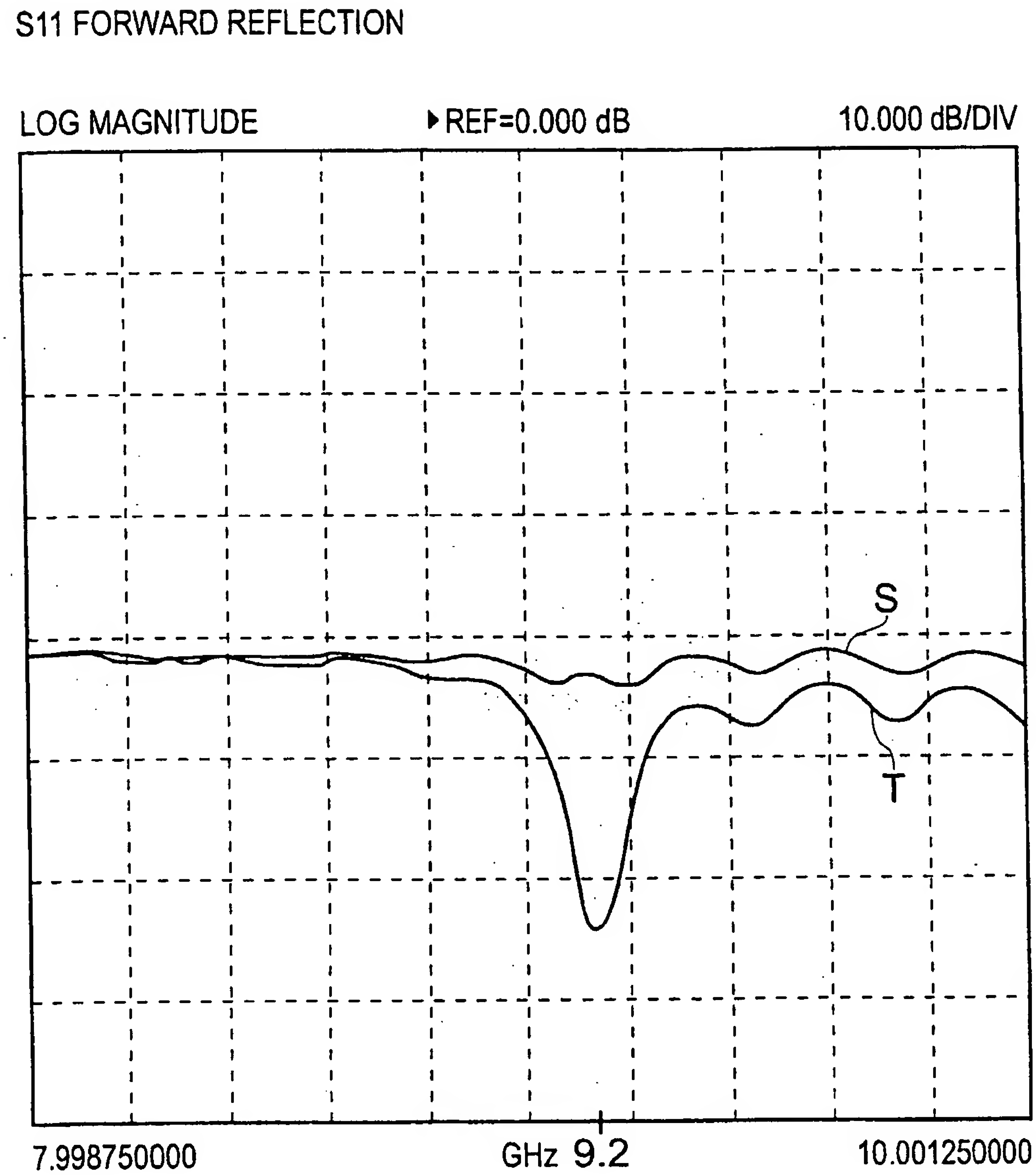

S11 FORWARD REFLECTION
LOG MAGNITUDE
REF=0.000 dB
10.000 dB/DIV
S
T
7.998750000
GHz 9.2
10.001250000

Fig. 2

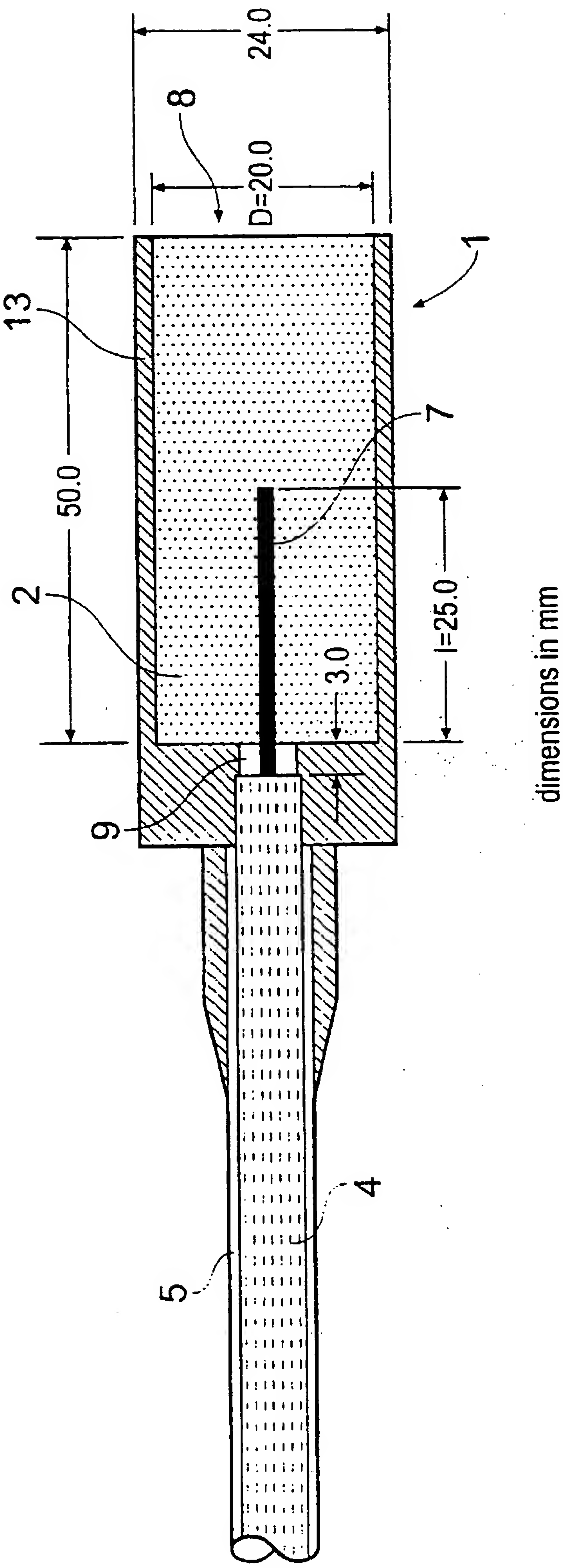


Fig. 3

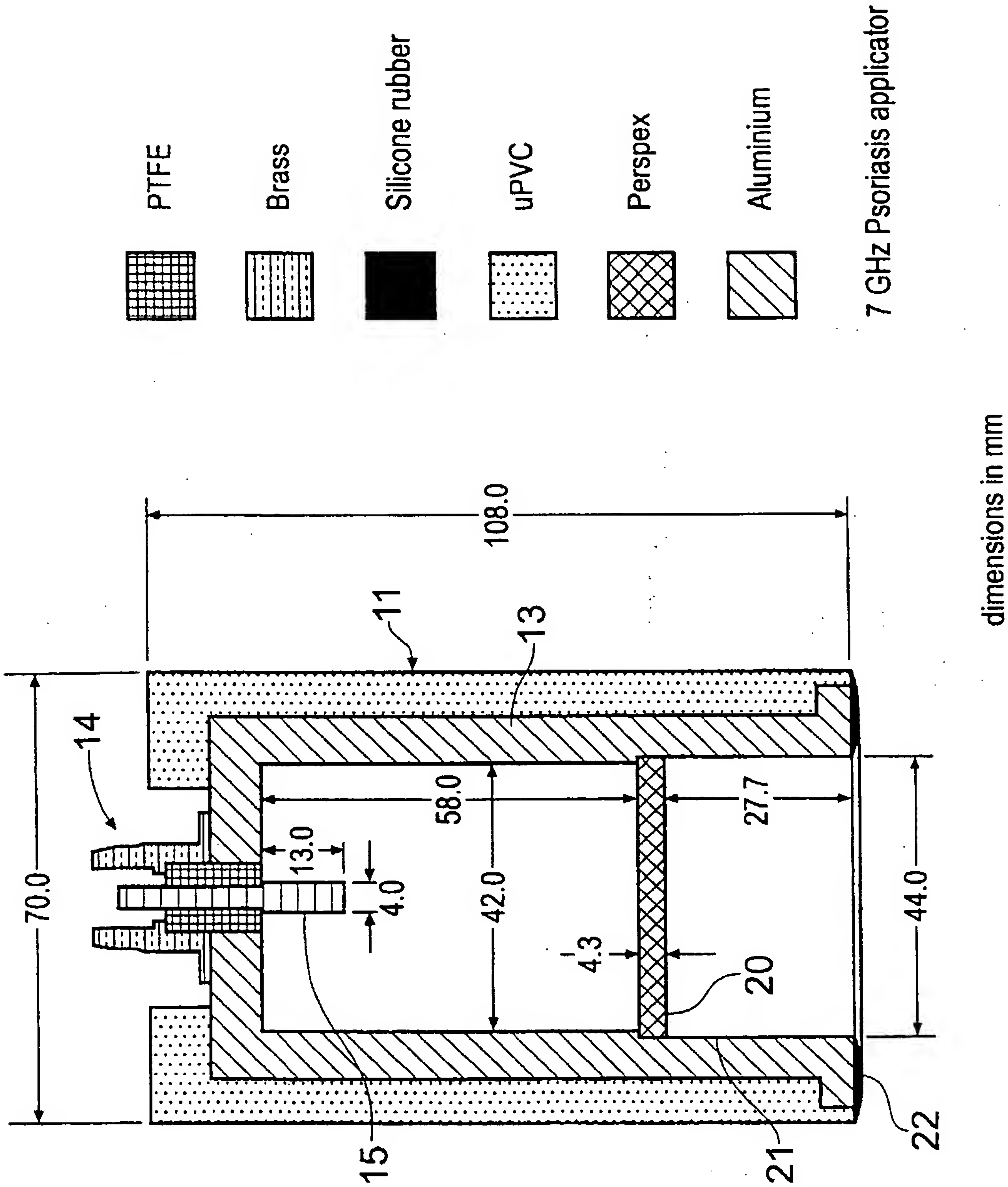

PTFE
Brass
Silicone rubber
uPVC
Perspex
Aluminium
7 GHz Psoriasis applicator
108.0
70.0
58.0
42.0
27.7
44.0
13.0
4.0
4.3
11
13
14
15
20
21
22
dimensions in mm

Fig. 4

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MICROWAVE APPLICATOR

This invention relates to a microwave applicator suitable for heating biological tissue and a method of heat treating surface tissue.

The applicants have previously proposed a microwave applicator for surgical use comprising a waveguide of reduced diameter by virtue of containing a dielectric of high permittivity. A coaxial electrical input generates microwaves in the TE_{11} mode within the dielectric and these radiate from the distal end face of the waveguide.

According to a first aspect, the present invention, consists in a microwave applicator comprising a coaxial electrical input and a waveguide filled with dielectric, a central conductor of the coaxial input extending longitudinally within one end of the waveguide to launch microwaves in the TM_{01} mode to travel to the distal end face of the waveguide so that microwaves are transmitted from the distal end face when in contact with the biological tissue to be treated.

The TM_{01} mode has a field pattern that is a good match with the coaxial input, better than the fundamental TE_{11} mode more commonly used, and which produces a simple transition between the coaxial input and the waveguide. The central conductor is preferably coaxially aligned within a circular waveguide and extends a short way within the waveguide to match the general dimensions of the waveguide, especially its length and diameter, and the permittivity of the dielectric and frequency of the electrical input.

The distal end face of the waveguide is preferably flat and radiates microwave energy with parallel wavefronts that advance into the biological tissue in contact with the distal end face and have minimum lateral spreading. The depth of penetration of the microwaves is dependent upon the frequency and electrical input power, but typically only a small distance of penetration is required for local heat treatment of tissue in microsurgery. In an alternative embodiment, the distal end face may be slightly domed and centred on the axis of the waveguide instead of being flat.

Another particularly important feature of the invention is the ability to make use of resonance in the waveguide so that reflections from the transition at the input end, and from the distal end face caused by the change in dielectric at each, are out of phase and therefore enhance forwards transmission when the distal end face is in contact with the biological tissue, and are in phase and therefore enhance reflection to the coaxial input when the distal end face is out of contact with the biological tissue. Therefore, microwave energy is only transmitted to any appreciable extent from the distal end face when in contact with the biological tissue to be treated, and this is a key safety feature in the mode of operation.

According to a second aspect, the invention consists in a microwave applicator comprising a waveguide, a coaxial electrical input with a central conductor extending longitudinally within one end of the waveguide to launch microwaves in the TM_{01} mode that travel to the distal end of the waveguide and are transmitted into biological tissue to be treated, a diaphragm of low loss dielectric material being provided within the waveguide so as to extend laterally of the waveguide to reflect the microwaves travelling along it, the longitudinal location of the diaphragm being selected in relation to the ends of the waveguide so that the coherent addition of the reflected waves from the waveguide junction and the diaphragm combine to create a wave which is of correct magnitude and phase to cancel the reflection from the coaxial waveguide junction.

Preferably, the thickness of the diaphragm and the permittivity of the dielectric material from which the diaphragm is made are selected to determine the magnitude of the rearward reflection of microwaves from the diaphragm for optimum cancellation of the rearward reflection in the coaxial input.

Preferably, the waveguide is air-filled, and the distal end of the waveguide is adapted to contact (or nearly contact) the surface tissue to be treated.

According to a third aspect, the invention consists in a method of heat treating surface tissue using the microwave applicator of the first or second aspect of the invention, the distal end face of the waveguide being brought into contact with the surface tissue, for treatment.

The invention will now be described by way of example with reference to the accompanying drawings, in which:

Figure 1 is a schematic axial section of a microwave applicator according to a first embodiment of the invention;

Figure 2 shows graphs of reflection coefficient against microwave frequency for the applicator of Figure 1 when the distal end is in air (graph S) and when in contact with biological tissue (graph T);

Figure 3 is a schematic axial section of a microwave applicator according to a second embodiment of the invention; and

Figure 4 is a schematic axial section of a microwave applicator according to a third embodiment of the invention.

The microwave applicator of Figure 1 consists of a waveguide 1 formed by a cylindrical body of dielectric 2 covered in an outer layer of aluminium foil 3, and a flexible coaxial cable input power supply 4 which is connected to the waveguide at one end so that the outer conductor 5 of the coaxial cable is electrically connected via a ferrule 6 to the aluminium tape 3, and the inner conductor 7 of the coaxial cable extends axially a short distance l into the dielectric body 2. The distal end face 8 of the waveguide 1 is flat and is covered by a layer of a non-stick polymer coating such as FEP.

Typically, for this microwave applicator to operate at a frequency of 9.2 GHz the dimensions of the waveguide are as follows; overall length L = 12.9 mm, diameter D = 5.2 mm, l = 5.9 mm; and the permittivity of the dielectric body k = 25. The dielectric is typically, Hik 500f dielectric material sold by Emerson & Cummings.

The performance of the microwave applicator of Figure 1 at different frequencies is shown by the graphs of Figure 2, in which Graph S shows the variation of reflection coefficient

S_{11} when the distal end face 8 of the applicator is in air, and in which Graph T shows the variation of reflection coefficient S_{11} when the distal end face 8 of the applicator is in contact with biological tissue to be treated. A drop in value of S_{11} in Figure 2 is indicative of a good microwave match, which is clearly demonstrated in Graph T at the designed operating frequency of 9.2GHz. Under these conditions, the applicator is transmitting maximum microwave energy into the biological tissue, but if the contact with the tissue is broken and the distal end face is in air or gas such as CO_2, then the transmitted energy falls immediately to a much lower level as the energy is reflected back to the coaxial cable input power supply 4.

It will be appreciated that a microwave applicator as shown in Figure 1 can be relatively inexpensive to manufacture, and can therefore be sold as a disposable product for microsurgery.

The microwave applicator Figure 1, being of reduced diameter of 5.2 mm, is suitable for insertion through a Trocar in laproscopic surgery to produce a local heating effect in a controlled manner adjacent the distal end face when in contact with biological material. For example, such an applicator may be used to destroy small surface tumours, for the treatment of ovarian cancer, or the treatment of endometriosis, or any surface lesions.

The second embodiment of the invention shown in Figure 3 is similar in configuration to that of Figure 1, and the same reference numbers are used for equivalent components. However, the waveguide 1 comprises a rigid aluminium cylindrical wall 3, typically 2 mm thick, and the dielectric body 2 is composed of a hard ceramic material, such as stabilised zirconia which has a permittivity k = 25. This dielectric material gives the applicator an ability to handle higher power levels, typically, up to 200 watts, compared with a power level of, say, 45 watts for the applicator of Figure 1. The applicator of Figure 3 is designed to operate at a lower frequency of 2.45 GHz, and also has an increased length L = 50 mm and diameter D = 20 mm. It will be appreciated that the diameter D is determined by the frequency of operation and permittivity K, and is selected to allow treatment of an appropriate size area of tissue, the increased area compared with Figure 1 being balanced by the increased power to provide an appropriate power density at the distal end 8 for the treatment intended.

The projection l of the central conductor 7 extends 25 mm into the dielectric body 2, and an air gap 9 is provided between the outer conductor 5 and dielectric of the coaxial cable input 4 and the waveguide 1 to allow the dielectric filling of the coaxial cable to expand..

The applicator of Figure 3 with a larger distal end 8 is more suitable for the treatment of larger surface breaking tumours, for example, primary and secondary tumours on the liver.

In an alternative embodiment of the invention, suitable for treating smaller liver tumours, the same configuration as that of Figure 3 is used but, the stabilised zirconia dielectric is replaced by alumina having a permittivity K = 10, and the dimensions are as follows: L = 18mm; D = 10mm; l = 11mm; and the operating frequency is 9.2 GHz. This applicator will treat a small area of tissue than that of Figure 3, but will cause less collateral damage.

The microwave applicator shown in Figure 4 consists of an air-filled waveguide 11 formed by an aluminium cylindrical wall 13 with an input connection 14 for a flexible coaxial cable input power supply which is connected to the waveguide at one end. The outer conductor of the coaxial cable is electrically connected to the wall 13 of the waveguide, and the inner conductor of the coaxial cable is connected to a conductor 15 which extends axially a short distance l into the waveguide 11. A Perspex diaphragm 20 is located laterally within the waveguide near the open end within a rebated section 21 which spaces it a distance w away from the open end 18. The diaphragm 20 has a thickness t. The operating frequency of the applicator is 7 GHz and the dimensions are typically L = 108mm; D = 42mm; l = 13mm; w = 27.7mm; and t = 4.3mm. These dimensions are selected in connection with the operating frequency and permittivity of the diaphragm so that when in use with the open end of the waveguide in contact with surface tissue to be treated, the rearward reflections of microwaves from the tissue and the transition between the coaxial cable 14 and waveguide 11 are substantially cancelled out by the reflections from the diaphragm which reduces reflections within the coaxial cable. In this balance situation, the majority of the microwave energy is then transmitted to the tissue being treated. In particular, the thickness t of the diaphragm 20 and the permittivity k of the material of which it is composed will determine the size of rearward reflection of

microwaves from it. The location of the diaphragm 20 relative to the ends of the waveguide 11 will determine the relative phases of the rearward reflections of the microwaves.

A microwave applicator such as that of Figure 4 would be suitable for skin treatments such as the treatment of psoriasis, especially because the end of the probe has minimal contact with the tissue being treated. Preferably, the edge of the waveguide 11 at the open end may be coated or fitted with some other protection for engagement with the tissue.

CLAIMS

1. A microwave applicator comprising a coaxial electrical input and a waveguide filled with dielectric, an inner conductor of the coaxial input extending longitudinally within one end of the waveguide to launch microwaves in the TM_{01} mode to travel to the distal end face of the waveguide so that microwaves are transmitted when the distal end face is contacted by the biological tissue to be treated.

2. A microwave applicator as claimed in claim 1 in which the inner conductor is axially aligned with the waveguide.

3. A microwave applicator as claimed in claim 1 or 2 in which the waveguide is a circular waveguide.

4. A microwave applicator as claimed in any one of the preceding claims in which the distal end face is substantially flat and normal to the axis of the waveguide.

5. A microwave applicator as claimed in any one of claims 1 to 3 in which the distal end face is flat or slightly domed and centred on the axis of the waveguide.

6. A microwave applicator as claimed in any one of the preceding claims in which the distal end face has a polymer coating.

7. A microwave applicator as claimed in any one of the preceding claims in which the length and diameter of the waveguide, the length of the inner conductor within the waveguide, and the permittivity of the dielectric material are selected so that at the designed operating frequency, the waveguide is in resonance.

8. A microwave applicator as claimed in any one of the preceding claims in which the waveguide is adapted so that in operation, when the distal end face is in contact with biological tissue to be treated, forwards transmission from the distal end face is enhanced by the relative phase of reflections from the distal end face and the input to the waveguide; and when the distal end face is in air or gas, reflections to the input are enhanced by the relative phase of reflections from the distal end face and the input to the waveguide.

9. A microwave applicator comprising a waveguide, a coaxial electrical input with an inner conductor extending longitudinally within one end of the waveguide to launch microwaves in the TM_{01} mode that travel to the distal end of the waveguide and are transmitted into biological tissue to be treated, a diaphragm of low loss dielectric material being provided within the waveguide so as to extend laterally of the waveguide to reflect the microwaves travelling along it, the longitudinal location of the diaphragm being selected in relation to the ends of the waveguide so that the phase of reflections from the diaphragm and said ends serve to reduce or cancel rearward reflections in the coaxial input.

10. A microwave applicator as claimed in claim 9 in which the thickness of the diaphragm, and the permittivity of the dielectric material from which it is made are selected to determine the magnitude of the rearward reflection of microwaves from the diaphragm for optimum cancellation of the rearward reflection in the coaxial input.

11. A microwave applicator as claimed in claim 9 or 10 which is air-filled.

12. A method of heat treating surface tissue using the microwave application of any one of claims 1 to 8 in which the end face of the waveguide is brought into contact with the surface tissue.

13. A method as claimed in claim 12 in which the surface tissue is internal tissue and the applicator is inserted into a body for treatment.

14. A method as claimed in claim 13 in which the insertion of the applicator is via a Trocar.

15. A method as claimed in claim 12 in which the surface tissue is the external skin of the body.

Application No: GB 0223564.6
Claims searched: 1 and 9
Examiner: Gareth Lewis
Date of search: 3 April 2003

Patents Act 1977 : Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance	
A	-	WO 99/56643 A1	(MICROSULIS) See abstract and figures
A	-	US 5364392	(FIDUS MED TECH CORP) See abstract and figures
A	-	EP 0294854 A2	(GLASGOW UNIVERSITY) See abstract and figures
A	-	WO 99/07297 A1	(DARTMOUTH COLLEGE) See abstract and figures
A	-	GB 2363077 A	(MICROSULIS) See abstract and figures

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^{V}:

A5R

Worldwide search of patent documents classified in the following areas of the IPC^{7} :

A61B A61N H01P

The following online and other databases have been used in the preparation of this search report :

WPI JAPIO EPODOC BIOSIS MEDLINE INSPEC